New Method to Determine the SFN Gain of a DVB-H Network with Multiple Transmitters

David Plets, Leen Verloock, Wout Joseph, Luc Martens
Dept. of Information Technology, Ghent University/IBBT
B-9050 Ghent, Belgium
david.plets@intec.ugent.be
wout.joseph@intec.ugent.be
luc.martens@intec.ugent.be

Etienne Deventer, Hugo Gauderis
Flemish Radio and Television Network (VRT)
B-1043 Brussels, Belgium
hugo.gauderis@vrt.be
etienne.deventer@vrt.be

Abstract

DVB-H networks allow high data rate broadcast services for hand-held terminals. A procedure to determine the SFN gain of such a DVB-H network will be investigated in this paper. Two methods are proposed, based on actual measurements of the electric-field strength in an SFN with three transmitters. Also standard deviations for the field strengths are provided. This SFN gain can be used for coverage planning of future networks.

Keywords
Digital Video Broadcasting - Handheld, DVB, DVB-H, SFN, multiple transmitters, SFN gain.

INTRODUCTION

The digital broadcasting standard DVB-H (Digital Video Broadcasting - Handheld) enables high data rate broadcast services for hand-held terminals (e.g., portable, pocket-size battery-operated phones). It is based on the specifications and guidelines of ETSI [1-4].

The broadband downstream channel features a useful data rate of up to several Mbps and may be used for audio and video streaming applications, file downloads, and many other kinds of services.

The standard builds on DVB-T (Digital Video Broadcasting - Terrestrial) [2], but is adapted for hand-held devices: it introduces time-slicing to reduce power consumption and includes the possibility to use MPE-FEC (Multi-Protocol Encapsulation-Forward Error Correction) at the link layer to improve the performance for mobile reception.

In this paper, two new methods to determine the SFN (Single Frequency Network) gain of a DVB-H system using actual signal strength measurements on an SFN with three transmitters in a suburban environment in Ghent, Belgium are developed. Here, SFN gain is defined as the increase of the field values when using multiple transmitters compared to field values when only one transmitter is active.

A subjective partition of a route in zones will be used to determine the SFN gain or network gain value of the DVB-H network. The zones are created based upon the presence of a transmitter nearby.

SFN gain can be taken into account when designing a DVB-H SFN. When multiple-transmitter networks are designed, based on the coverage of a single transmitter with a specified transmitting power, knowledge of the SFN gain can be used to decrease the transmitting power of each transmitter in the SFN, while still meeting the carrier to interference-plus-noise ratio (CINR) requirement [5]. In network planning, it can also be used to increase the distance between transmitters, lowering the number of required base stations. This paper can thus be used for practical network design by operators and/or broadcasters.

The transmitting network, the measurement method, and the procedure used to calculate the SFN gain are described in the following Section. Then the results are discussed and finally, the conclusions are presented. This paper will allow to make an estimation of the SFN gain of DVB-H networks.

METHOD

Transmitting Network

The transmitting network is located in a suburban environment in Ghent, Belgium. The SFN contains three base station antennas (BS). The locations of the transmitting base stations are a building at the Keizer Karelstraat (Belgacom building, BS 1), a tower at the Rooigemlaan-Groendreef (Bemilcom mast, BS 2), and a building of Ghent University at the Ledeganckstraat (Ledeganck building, BS 3). Figure 1 shows a map of Ghent with the location of the three base stations marked with black circles. All transmitting antennas Tx are omnidirectional. The heights of these Tx are $h_{Tx} = 64$ m, $h_{Tx} = 57$ m, and $h_{Tx} = 63$ m, respectively. The EIRP (Equivalent Radiated Power) used for these Tx is 39.93 dBW, 36.62 dBW, and 40.90 dBW, respectively. The constellation used for the tests is 16-QAM 1/2 with an MPE-FEC rate of 7/8, corresponding with a useful bit rate of 9.68 Mbps. This constellation is preferred because of its satisfactory behavior regarding both bit rate and coverage area [6, 7].

Measurement method to assess SFN Gain SFNG

The measurements are performed with a DVB-H tool implemented on a PCMCIA (Personal Computer Memory Card International Association) card with a small receiver antenna Rx. The gain of the antenna is – 5 dBi. The PCMCIA card is plugged into a laptop, which is used to collect and process the measurement data.

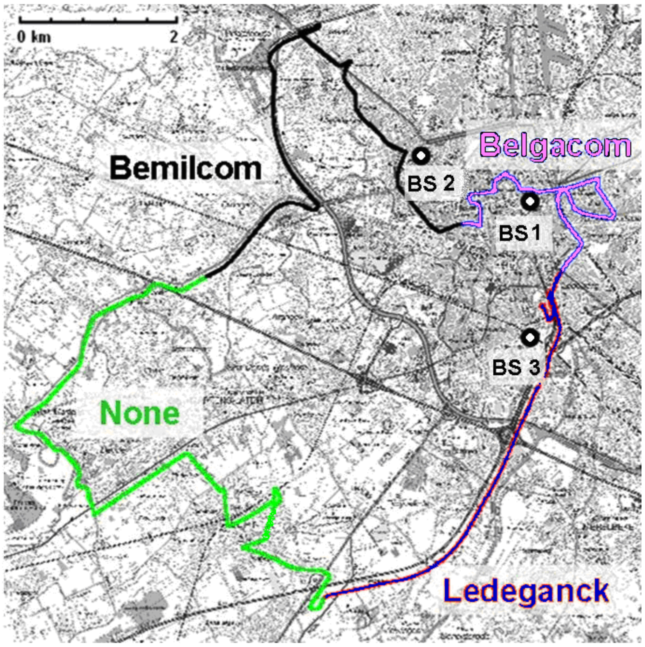

Figure 1. Map of Ghent with the three transmitting antennas (indicated with black circles) and the route selected for SFN gain calculation, divided into four different zones (blue: zone Ledeganck, green: zone None, black: zone Bemilcom, and pink: zone Belgacom).

Every 0.5 s, a sample is recorded. The tool logs parameters as CINR, FER (Frame Error Rate), MFER (Multi-Protocol Encapsulation FER), and electric-field strength.

Location and speed are recorded with a GPS device. To measure the electric-field value [dBμV/m], the AGC (Automatic Gain Control) value is used. This AGC value corresponds with a certain received power P_R [dBm]. From P_R, the electric field E [dBμV/m] can be calculated as follows [8, 9]:

$$E = V_O + k + A, \qquad (1)$$

with V_O the output voltage of the antenna in dBμV, k the antenna factor in dB(1/m) and A the cable loss in dB. A is zero in this case.

V_O can be calculated as follows:

$$V_O = 20 \cdot \log\left(10^6 \cdot \sqrt{50 \cdot \frac{10^{\frac{P_R}{10}}}{1000}}\right). \qquad (2)$$

k is defined as [8, 9]:

$$k = 20\log(f) - 29.7707 - G_r, \qquad (3)$$

with f the frequency under consideration (in MHz) and G_r the gain of the receiver antenna (in dBi). The tool has been validated by measurements with a spectrum analyzer and good agreement was obtained (field values differ only 0.37 dB on average over a route of 50 km).

The analysis in this paper will be performed for mobile reception at a height of 1.5 m inside a small van, driving around at traffic speeds of 50-70 km/h (common in Belgium).

SFN Gain

To determine the SFN gain for the network with 3 transmitters in Ghent, a route of about 50 km (or about 1h30min driving) has been chosen. The route stretches from the very centre of Ghent to the municipalities that surround Ghent (see Figure 1).

Four scenarios have been investigated:

- scenario 1: transmitter Belgacom (BS 1) active, other Tx off
- scenario 2: transmitter Bemilcom (BS 2) active, other Tx off
- scenario 3: transmitter Ledeganck (BS 3) active, other Tx off
- scenario 4: transmitters Belgacom, Bemilcom, Ledeganck active

Figure 1 shows the investigated scenarios. The transmitters are marked with black circles. The route is divided into four parts or zones: three parts close to each of the three transmitters (zones Bemilcom, Belgacom, and Ledeganck where the respective transmitters are active, see Figure 1) and one part further away from the three transmitters (zone None, see Figure 1). By comparing the average field values in the different parts for the different scenarios, we calculate the SFN gain. The SFN gain will be calculated in two ways: using formula (4) and using formula (5).

First, some notations used in formulas (4) and (5) are explained below.

- $E_{ij}^{<zone>}$ is the j-th sample of the electric-field strength in zone <zone> for scenario i. (i = 1,…, 4), <zone> = Bemilcom (Bemil), Belgacom (Bel), Ledeganck (Lede), None (None).
- $N_{i,<zone>}$ is number of electric-field strength samples recorded in zone <zone> for scenario i. (i = 1,…, 4), <zone> = Belgacom (Bel), Bemilcom (Bemil), Ledeganck (Lede), None (None).
- $SFNG_j$ = SFN gain according to method j (j = 1, 2).

The first method to determine the SFNG ($SFNG_1$, formula (4)) is based on calculating the difference in dBμV/m of the measured electric-field strength in the zones around the nearest transmitter, when all three Tx are active (scenario 4) and the measured electric field strength for scenarios 1, 2, 3 in the zones Bel, Bemil, Lede (where only the Tx of the corresponding zone is active).

The second method to determine the SFNG ($SFNG_2$, formula (5)) is based on calculating the difference of the measured electric-field strength in the zone None for scenario 4 (all Tx active) and the measured electric field strength in zone None for scenarios 1, 2, and 3 with only one Tx active.

SFN gain $SFNG_1$ [dB]=

$$\frac{1}{N_{4,Bel}+N_{4,Bemil}+N_{4,Lede}}\cdot\left(\sum_{j=1}^{N_{4,Bel}}E_{4j}^{Bel}+\sum_{j=1}^{N_{4,Bemil}}E_{4j}^{Bemil}+\sum_{j=1}^{N_{4,Lede}}E_{4j}^{Lede}\right)-\frac{1}{N_{1,Bel}+N_{2,Bemil}+N_{3,Lede}}\cdot\left(\sum_{j=1}^{N_{1,Bel}}E_{1j}^{Bel}+\sum_{j=1}^{N_{2,Bemil}}E_{2j}^{Bemil}+\sum_{j=1}^{N_{3,Lede}}E_{3j}^{Lede}\right)\quad(4)$$

SFN gain $SFNG_2$ [dB]=

$$\frac{1}{N_{4,None}}\cdot\left(\sum_{j=1}^{N_{4,None}}E_{4j}^{None}\right)-\frac{1}{N_{1,None}+N_{2,None}+N_{3,None}}\cdot\left(\sum_{j=1}^{N_{1,None}}E_{1j}^{None}+\sum_{j=1}^{N_{2,None}}E_{2j}^{None}+\sum_{j=1}^{N_{3,None}}E_{3j}^{None}\right)\quad(5)$$

Table 1. Average values of the electric field (dBµV/m) and standard deviations [dB] in the different zones for the different scenarios.

		zone				
scenario		**Bel**	**Bemil**	**Lede**	**None**	**All data**
Belgacom (1)	E [dBµV/m]	87.33	71.75	77.81	68.06	75.90
	σ [dB]	8.28	4.08	6.76	1.65	9.68
Bemilcom (2)	E [dBµV/m]	67.09	80.14	66.61	64.99	69.29
	σ [dB]	3.12	8.82	2.06	1.61	7.47
Ledeganck (3)	E [dBµV/m]	75.24	71.74	89.28	68.71	74.30
	σ [dB]	5.19	3.85	10.96	2.84	8.56
All three BS (4)	E [dBµV/m]	88.65	83.05	92.53	69.74	82.42
	σ [dB]	7.43	7.38	9.92	3.71	11.08

RESULTS

Table 1 shows the average values of the electric field and the standard deviations σ in the different zones and for the different scenarios. It shows that for scenarios 1-3, the electric field is the highest near the active transmitter: e.g., E = 87.3 dBµV/m in zone Bel for scenario 1, which is much higher than the values of E in zones Bemil (71.8 dBµV/m), Lede (77.8 dBµV/m) and None (68.1 dBµV/m) . Table 1 also shows the average electric-field strength of each scenario along the whole route ("All data"). These values will be used to calculate the SFNG according to the proposed methods.

Figures 2, 3, and 4 compare the value of the measured electric field as a function of the sample number for scenario 4 with the measured field strength for scenarios 1, 2 and 3, respectively. The different zones are indicated (on top of the figure) by using different background colors, corresponding with the colors used in Figure 1. For scenarios 1-3, the highest electric fields are of course measured near the active transmitter. The fields for scenario 4 in the respective zones are more or less equal to, but slightly higher than the fields measured when only one transmitter is active in the zone near that transmitter.

To know the actual SFN gain using the *first method* of Section ‘SFN Gain’ (formula (4)), we calculate the average electric-field strength of scenario 1 in zone Belgacom, scenario 2 in zone Bemilcom, and scenario 3 in zone Ledeganck. This value is then compared with the average electric field in zones Belgacom, Bemilcom, and Ledeganck for scenario 4 (all Tx active), using formula (4). The average value for scenario 1, 2, 3 in zone Belgacom, Bemilcom, Ledeganck respectively is 85.34 dBµV/m (Table 1, standard deviation σ = 9.89 dB). The average value for scenario 4 in zones Belgacom, Bemilcom, and Ledeganck (see Table 1) is 87.59 dBµV/m (σ = 8.66 dB). These average values are weighted with the number of samples for each scenario in each zone. The resulting SFN gain $SFNG_1$ is equal to the difference of these two values: 2.26 dB. The difference between the standard deviations σ of the electric-field strengths that have been taken into account for the respective methods, is limited (only 1.21 dB).

The SFN gain is also calculated using the *second method* of Section ‘SFN Gain’ in zone None using formula (5). The average value of scenarios 1-3 in zone None is 67.36 dBµV/m (Table 1, σ = 2.67 dB). The average value of scenarios 4 in zone None is shown in Table 1 and is equal to 69.74 dBµV/m (σ = 3.71 dB). When taking the difference of these two values, we obtain a value for $SFNG_2$ = 2.39 dB. This value is very similar to the value of $SFNG_1$ = 2.26 dB using the first method. Again, the difference between the standard deviations σ are limited (1.04 dB). We can conclude that both proposed methods deliver similar results and the SFN gain for the considered network is about 2.3 dB. This value can be taken into account when designing a DVB-H network.

CONCLUSIONS

In this paper, a new procedure to determine the SFN gain of a DVB-H network with multiple transmitters is proposed. Actual measurements of the DVB-H electric-field strength are performed and two methods to calculate the SFN gain are proposed. The two methods give similar results and the SFN gain for the considered network is about 2.3 dB. The standard deviation does not differ much (about 1 dB) for the different considered scenarios. This value for the SFN gain can be used for future DVB-H design.

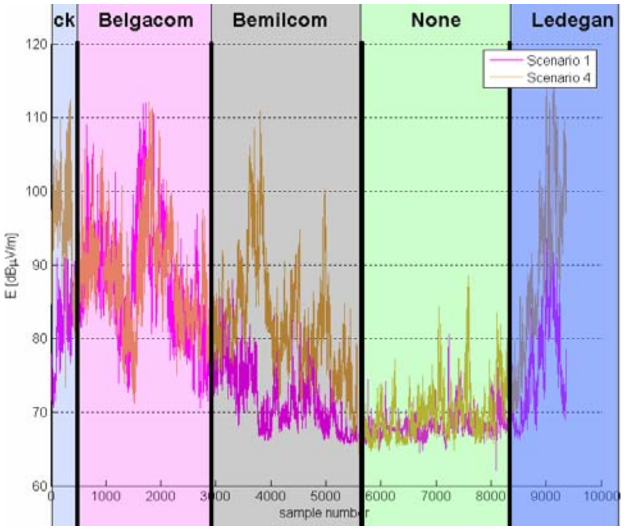

Figure 2. The measured electric field in the different zones along the route of 50 km for scenarios 1 and 4.

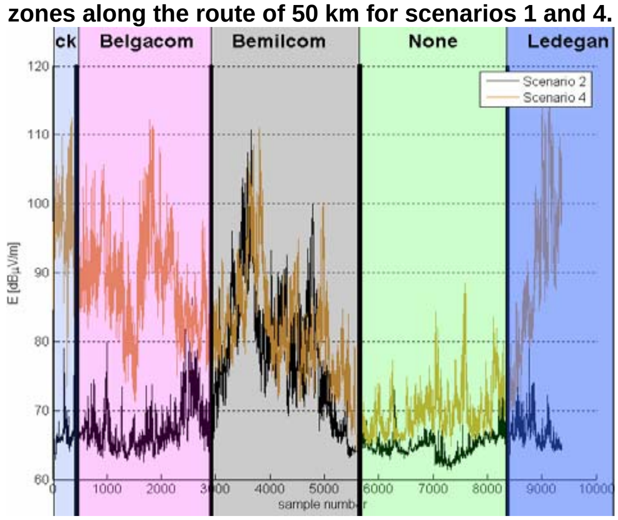

Figure 3. The measured electric field in the different zones along the route of 50 km for scenarios 2 and 4.

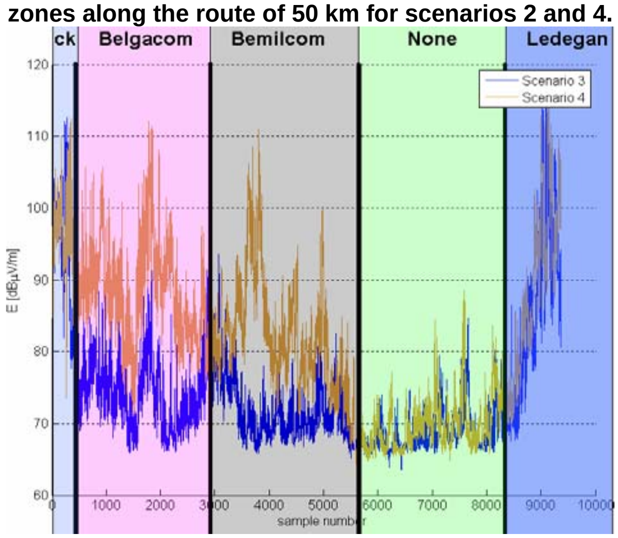

Figure 4. The measured electric field in the different zones along the route of 50 km for scenarios 3 and 4.

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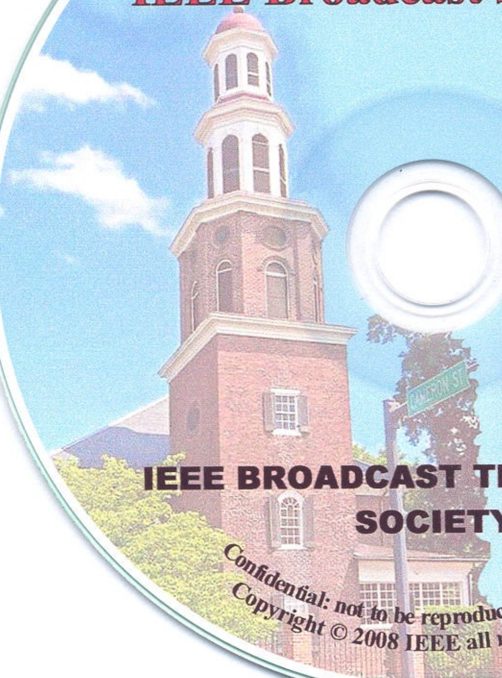

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